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In re Application of: John E. Fagan, et al. **Group Art: Unknown**

Application No.: Not Yet assigned **Examiner: Unknown**

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For: NAVIGATION SYSTEM USING LOCALLY AUGMENTED GPS

Mail Stop Patent Application
Commissioner for Patents
P.O. Box 1450
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INFORMATION DISCLOSURE STATEMENT

List of Sections Forming Part of This Information Disclosure Statement

The following sections are being submitted for this Information Disclosure Statement:

1. [X] Preliminary Statements
2. [ ] Form PTO-1449 (Modified)
3. [X] Statement as to Information Not Found in Patents or Publications
4. [ ] Identification of Prior Application in Which Listed Information Was Already Cited and for Which No Copies Are Submitted or Need Be Submitted
5. [ ] Cumulative Patents or Publications
6. [ ] Copies of Listed Information Items Accompanying this Statement

7. [ ] Concise Explanation of Non-English Language Listed Information Items

   7A. [ ] EPO Search Report

   7B. [ ] English Language Version

8. [ ] Translation(s) of Non-English Language Documents

9. [ ] Concise Explanation of English Language Listed Information Items (Optional)

10. [X] Identification of Person(s) Making this Information Disclosure Statement

Section 1. Preliminary Statements

Applicants submit herewith patents, publications or other information of which they are aware, which they believe may be material to the examination of this application and in respect of which there may be a duty to disclose.

The filing of this information disclosure statement shall not be construed as a representation that a search has been made (37 C.F.R. § 1.97(g)), an admission that the information cited is, or is considered to be, material to patentability or that no other material information exists.

The filing of this information disclosure statement shall not be construed as an admission against interest in any manner. Notice of January 9, 1992, 1135 O.G. 13-25, at 25.

Section 2. Form PTO-1449 (Modified)

[ ] A Completed Form PTO-1449 (Modified) is attached hereto.

Section 3. Statement as to Information Not Found in Patents or Publications (Information Not Listed in Form PTO-1449(Modified))

In today's fast-paced society, travel has become an integral part of life in both business and pleasure. Among the many forms of travel, air travel has considerably

increased in recent years to become one of the main staples. In 1995, the air travel system moved 555 million passengers. The Federal Aviation Administration forecasts predicted 800 million passengers per year will be flying in less than a decade, with more than one billion flying annually by 2010. This rapid increase has raised concerns about the ability of present-day navigational systems to provide the precise positional awareness that is essential to manage the increased volume of planes and passengers.

Present-day aircraft navigation consists of utilizing several different navigational aids to form a complete navigation system; a single system to provide position information through all phases of flight does not exist. Consequently the purchase and maintenance of a complete aircraft navigation system has been extremely expensive and complex.

A system that is being explored as a possible sole means navigation system is the satellite-based global positioning system (GPS).

Global Positioning System

The Global Positioning System (GPS) is a navigation system consisting of a constellation of twenty-four satellites in orbit approximately 11,000 nautical miles above the earth's surface. The GPS constellation is comprised of six orbital planes, each containing four satellites spaced at 60 degree increments. This spacing is in order to ensure that at least four satellites can be viewed from any point on the earth's surface at any given time. GPS navigation is based on satellite ranging: position is determined by measuring the distance of a receiver from a group of satellites in space. The satellites act as precise reference points from which receivers on the ground calculate their position.

Satellite Ranging

In theory, satellite ranging requires a minimum of three satellites to calculate the position of the receiver. The distance to each satellite is calculated by receiving unique timing codes from each of the three satellites and calculating the time it took for each timing code to travel from the satellite to the receiver antenna. These timing codes travel at approximately the speed of light (3×10^8 meters per second). Therefore, once the travel time, T_t (s), is known the distance can be calculated from the following equation. These calculated distances are referred to as pseudo-ranges.

$$\text{Distance(m)} = T_t * 3 \times 10^8 \text{ m/s}$$

Because the travel time is a calculated value, it is susceptible to several different types of errors. For this reason, it is often necessary to correct for these errors when the user requires a precise position measurement.

With one calculated distance, the receiver knows that it is located somewhere on the surface of an imaginary sphere that is centered on the satellite whose distance is known. A second distance measurement to a different satellite refines the known position of the receiver as a result of simple mathematics. Geometrically, the intersection of two spheres is a circle; therefore the receiver must lie on a circle. A distance measurement from a third satellite narrows the position to two points on a circle. In theory, one of the two calculated positions can be discarded because it will furnish the receiver with a position that is not within the realm of possibility (i.e., thousands of kilometers away from the earth). However, in practice a fourth distance measurement is taken to serve two purposes. The first purpose is to verify which of the two points is the actual location of the receiver. Additionally, the fourth distance measurement is used to compensate for the inaccuracies of the receiver's clock. This is very important because if the receiver's clock and the satellites clock are not synchronized, the calculated position will be wrong.

Limitations of G.P.S.

The Global Positioning System (G.P.S.) has been recognized as the future of navigation for the aviation community. The greatest hurdle that the global positioning system must overcome is an inability to provide quality suitable for primary-means aircraft navigation. G.P.S. fails to provide the accuracy, integrity, availability, and continuity of service, which are currently required for this type of service. These downfalls are a result of several different error sources. The sources include satellite and receiver clock inaccuracies, ephemerid error, the ionosphere, and multipath.

The atomic clocks that are used in satellites are extremely accurate; however, they still have small deviations that can manifest in the form of calculation errors. G.P.S. receivers do not use atomic clocks and are therefore even more susceptible to timing errors.

Because satellites drift slightly from their predicted orbits, their exact position relative to the earth is not always known. This uncertainty in position can lead to errors in the receiver's position calculations. This type of error is referred to as ephemerid error.

All information that is transmitted by the satellites is in the form of radio signals. Unfortunately, radio waves are susceptible to many types of interference. One possible source of interference is the atmosphere, specifically the ionosphere and troposphere. The ionosphere, which is the atmospheric layer located from 50 to 500 kilometers above the earth's surface, contains a large number of free electrons. These electrons appear opaque to the radio waves and therefore cause the waves to deflect. The troposphere, the layer of the atmosphere from ground level to approximately 8 km above the earth's surface, is also a source of interference. This interference is a result of variations in the composition of the medium through which the radio waves are traveling. Both of these layers cause a deviation in the radio waves' paths, which introduces a delay in transmission time and can lead to erroneous distance calculations. This error is referred to as atmospheric delay.

Another phenomenon that causes flawed transmission times is known as multipath. Multipath is similar to atmospheric delay, except the deflections are caused by terrestrial objects such as mountains, buildings, large antennas and other obstacles.

It is believed the solution to these problems is a differential G.P.S. system that can compensate for the errors and thus provide the accuracy, integrity, and availability that is required for all aspects of flight.

Differential G.P.S.

Contingencies, such as the accuracy of the satellite's clock, ephemeris error, the refractive nature of the atmosphere, or multipath, may combine to create a GPS signal that is simply not accurate enough with which to navigate. Differential GPS is a method by which GPS signals that contain errors may be augmented to improve the quality of the signal. This is accomplished by providing corrections to the errors that exist in a normal GPS signal. To provide these corrections, at least one reference receiver must be used to resolve the inaccuracies in the GPS signal.

The reference receiver is a stationary receiver whose exact position is known, by means of a precise survey. This reference receiver calculates error corrections by reverse engineering the position calculations. The reference receiver uses its known location and the predicted location of the satellite and its orbit to calculate the approximate distance, or pseudo-range, between the reference receiver and the satellite. This distance is then divided by the speed of light to calculate the expected travel time of the GPS signal from the satellite to the receiver. This predicted travel time is then compared to the actual travel time. The difference between the two

measurements is the error in the GPS signal and is referred to as timing error. This timing error results in an inaccurate pseudo-range to the satellite, which must be corrected in order to improve the accuracy of the GPS signal. In order to accomplish this, a pseudo-range correction corresponding to the calculated error is transmitted to any receiver in the local vicinity so that it may adjust its position accordingly. This receiver uses the error correction to augment the GPS signal in an effort to improve its accuracy. This principle of correcting for uncertainties in the GPS signal by using reference receivers to calculate error corrections is known as Differential G.P.S. (DIPS). DIPS can be implemented by several different methods.

W. A. A. S. (Wide Area Augmentation System) is an augmentation of the G.P.S., which includes integrity broadcast, differential corrections and additional ranging signals. W.A.A.S. is being developed to provide the accuracy, integrity and availability required to support all phases of flight including precision approaches and landings.

Wide Area Augmentation System

Wide Area Augmentation System (W. A. A. S.) is one method by which differential G.P.S. can be implemented to improve the accuracy of the standard G.P.S. signal. This method is referred to as wide area because it was designed to provide differential corrections for the entire United States. W. A. A. S. is implemented through the use of 25 ground reference stations and two master stations, all of which are linked together to form a network across the United States.

Each reference station has been surveyed in order to determine its precise location. These ground reference stations each receive position data from the G.P.S. constellation. Utilizing this data received from the G.P.S. satellite, along with its known location, the reference station calculates any error that exists in the G.P.S. signal. Each station in the network then relays its pseudo-range corrections to a master station, The master station then formats all of the correction information into a message. The message is broken into sections dedicated for specific geographical regions within the United States. This correction message is then up linked to a geostationary communication satellite. This satellite travels in the same orbit as the earth and is therefore always located in the same position relative to the earth. The message is then broadcast from the geostationary satellite on the same frequency as G.P.S. to GPS/W. A. A. S. receivers that are within the broadcast coverage area of the W. A. A. S. The correction message is then combined with the standard GPS signal to form a more precise position signal for navigation.

The W. A. A. S. signal drastically improves the accuracy of the GPS signal thus lending itself to several new applications, such as aircraft navigation. However, due to its space-based nature, the W. A. A. S. signal is susceptible to some of the same problems as standard GPS, primarily the latencies that occur from being transmitted from space through the earth's dense atmosphere. These latencies are not an issue in normal flight and landings; however, in instances where higher precision is essential, the W. A. A. S. will not provide an accurate enough signal. For this reason the Local Area Augmentation System is being developed in accordance with the present invention in an effort to provide the accuracy, integrity and availability required for precision approaches.

Local Area Augmentation System

Another method of implementing differential GPS is through the use of a Local Area Augmentation System (LAAS). LAAS was originally designed so that one system would provide differential corrections for all receivers within a 20 mile radius, thus referred to as local. A Local Area Augmentation System will consist of at least three precisely surveyed ground reference stations and a master reference station, all located in close proximity of each other. Each of these reference stations will receive GPS position information and relay this position to the master reference station. The master reference station uses the received position information, as well as the surveyed position of the reference stations, to calculate any error that exists in the GPS signal. The master ground station will then form a correction message using this calculated error. It then broadcasts this message using a VHF transmitter to all GPS/LAAS receivers within the specified area. Because the LAAS is ground based, it does not suffer from the same transmission problems that affect WAAS and standard GPS. Therefore, it has the potential to provide the quality of signal for applications that demand more precise position information. One of these applications is precision aircraft approaches and landings. The LAAS is intended to become the primary radio navigation system to support Category II and III precision approach operations, particularly where those operations cannot be supported by the precision approach capability of the WAAS.

Motivation

Presently aircraft navigation is provided by several different navigational aids such as ILS, DME, ADF, VOR and others. None of these navigational aids can provide in route navigation as well as precision and non-precision approaches and landings. For this reason, the use of navigational aids in an aircraft is very costly, because not one but a combination of the above systems must be used to provide total aircraft navigation. Another drawback to present-day navigation systems is the

high pilot workload; he must constantly manage several different systems in order to navigate the airplane. Consequently this can lead to problems during flight. As a result, the Federal Aviation Administration (FAA) has embarked on an aggressive program to make satellite-based navigation technology available for use throughout the National Air Space System (NAS). Satellite-based navigation services will provide significant economic and safety benefits to the entire aviation community.

The benefit of using G.P.S. is that it will eliminate the need for more than one navigational aid, which will be much more cost-effective as well as reduce the pilot workload. However, research has proven the standard G.P.S. cannot provide the precision that is necessary for complete aircraft navigation. Therefore, differential G.P.S. is being used as a solution. W. A. A. S. has already shown that they can provide the accuracy needed for all stages of flight; however, it does not provide the integrity required by all stages of precision approach and landing. It is believed that L. A. A. S. in accordance with the present invention will provide better accuracy and integrity than W. A. A. S.

Section 4. Identification of Prior Application in Which Listed Information Was Already Cited and for Which No Copies Are Submitted or Need Be Submitted

This application relies, under 35 U.S.C. § 120, on the earlier filing date of prior application Serial No. _______, filed on _________ (date).

(complete the following, if applicable)

[ ] This application also relies, under 35 U.S.C. 120, on the earlier filing date of prior application Serial No. ______, filed on ______ (date).

The following references were submitted to, and/or cited by, the Office in the prior application(s) and therefore, are not required to be provided in this application:

Section 5. Cumulative Patents or Publications

STATEMENT

____________ is cumulative of the following patents or publications listed on Form PTO-1449:

In accordance with 37 C.F.R. § 1.98(c), a copy of only ____ is being submitted with this Information Disclosure Statement.

Section 6. Copies of Listed Information Items Accompanying this Statement

Legible copies of all items listed in Form PTO-1449 (Modified) accompany this information disclosure statement.

[ ] Exception(s) to above:

[ ] Items in prior application from which an earlier filing date is claimed for this application, as identified in Section 4.

[ ] Cumulative patents or publications identified in Section 5.

Section 7. Concise Explanation of Non-English Language Listed Information Items

Section 7A. Concise Explanation of Non-English Language Listed Information Items - EPO Search Report

The relevance with respect to the following citations listed on Form PTO-1449:

is submitted on the basis of accompanying:

(check the appropriate item)

[ ] EPO search report that is in the English language,

[ ] EPO search report that is not in the English language and that is accompanied also by an English language version of the EPO search report,

that issued on the corresponding European patent application.

Section 7B. Concise Explanation of Non-English Language Listed Information Items - English Language Version of EPO Search Report

Section 8. Translation(s) of Non-English Language Documents

[ ] Submitted herewith is an English translation of the following foreign language patents, publications or information or of those portions of those patents, publications or information considered to be material:

(complete the following, if applicable)

[ ] No English language translations of the foreign language parents, publications or information or parts thereof are readily available, except for those listed above.

[ ] The following foreign language documents submitted are believed to be the equivalent or substantial equivalent of the English language documents identified below, which are also submitted herewith.

Section 9. Concise Explanation of English Language Listed Information Items (OPTIONAL)

Section 10. Identification of Person(s) Making this INFORMATION DISCLOSURE STATEMENT

The person making this statement is the attorney who signs below.

Respectfully submitted,

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